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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAMME OF THE

MADISON MEETING

AT

MADISON, WISCONSIN

June 21–22–23, 1948

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BULLETIN

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MADISON MEETING, JUNE 21–22–23, 1948

By gracious invitation of the University of Wisconsin, the American Physical Society will hold our **1948 Summer Meeting in the East** (286th Meeting) in its buildings at Madison, Wisconsin, on Monday, Tuesday, and Wednesday, June 21st, 22nd, and 23rd, 1948. There will be invited and contributed papers on the general programme, and a group of six invited papers in two sessions organized by our Division of Electron Physics. Madison is on Central Standard Time.

Invited speakers on the general programme are G. D. Adams (with A. T. Nordsieck), G. Antonoff, R. G. Herb, H. M. James, Arthur Roberts, R. G. Sachs, J. H. Van Vleck, Gregor Wentzel, M. W. White, and E. P. Wigner.

Invited speakers of the Division of Electron Physics are M. A. Herlin, T. Holstein, E. F. Lowry, J. P. Molnar (with J. A. Hornbeck), A. O. C. Nier, and L. A. Wooten.

Contributed papers are distributed among six sessions scheduled for Monday morning and afternoon, Tuesday morning and afternoon, and Wednesday morning.

Hotels in Madison are the Loraine, the Belmont, and the Park. Members who read the summons card carefully and acted accordingly were able to arrange for rooms and meals in a University dormitory, Elizabeth Waters Hall: this opportunity will have lapsed by the time the Bulletin reaches the membership. The Local Committee remarks that "the University constitutes so large a part of Madison that visitors should have no difficulty finding it." The registration desk will be located just inside the Charter Street entrance of Sterling Hall, one block north of University Avenue. Members will be told there how to reach Elizabeth Waters Hall. All members and guests are asked to register.

The **dinner of the Society** will be held at 7:00 o'clock on Monday evening in the Loraine Hotel: the price will be $2.75 per plate. Members and guests should make reservations by writing or telegraphing to Dr. R. G. Sachs, Department of Physics, University of Wisconsin, Madison, Wisconsin: a reservation form is printed on the inside back cover page of this Bulletin. The deadline is given as June 17th; no guarantee can be made of places to people whose orders are received later.

The **Council** of the American Physical Society will meet at 4:30 P.M. on Monday in Room 124, Sterling Hall, unless contrary notice is sent to its members.

Post-deadline papers. The Council, availing itself of an amendment to the By-Laws adopted on 30 January 1948, announces that "The Council or its designates will consider the admission, to a special supplementary programme, of a limited number of additional papers of which the abstracts reach the office of the Society not later than Tuesday 15 June." Do not regard this as a guarantee! The idea is to make possible the presentation of a small number of very recent achievements of very special importance. The abstracts of the post-deadline papers which are thus accepted (if any are) will not be published: the titles will be mimeographed

and distributed at the registration desk, and the papers will be given at the end of Session K.

Placement Register. There will be **NO** Placement Register at this meeting.

Prospective meetings of the Society are planned as follows: Pasadena, California, June 24–26; Chicago, November 26–27; New York, January 27–29, 1949.

General Rules Relating to Papers

The time allowed for the oral presentation of a contributed paper is ten minutes at most. The time allowed for the oral presentation of each invited paper is stated in the Bulletin.

When two or more papers are contributed by the same member, all but one are placed on the "supplementary programme." (A paper by two or more members is credited, for this purpose, to the person first named in its by-line.) For each paper on this programme a session is indicated, at the end of which it may be offered: but the presiding officer may require that it be given in fewer than ten minutes, or may read it by title.

Titles and abstracts of the papers contributed to the Madison meeting are printed in the following pages. Proofs of the abstracts have not been submitted to the authors, and the proofreading is always cursory because of the need for haste: but the authors have opportunity to correct their proofs before the abstracts appear in the *Physical Review*. Overlong abstracts sometimes appear in a form unexpected by the authors, because there is not time to consult them before the abstracts are amputated to fit the requirements stated on the summons card.

Speakers must not forget to retrieve their lantern slides before leaving Madison. The Local Committee is in no wise obligated to keep or to return them.

Karl K. Darrow, *Secretary*
American Physical Society
Columbia University
New York 27, New York

EPITOME OF THE PROGRAMME

Monday Morning

A. Solid and liquid states. Bascom 165.
B. E. P. Wigner, G. Wentzel, R. G. Herb. Bascom 272.

Monday Afternoon

C. H. M. James, G. Antonoff, M. W. White. Bascom 272.
D. Reactions of transmutation; cosmic rays. Bascom 165.

Tuesday Morning

E. General nuclear physics; apparatus of nuclear physics. Bascom 165.
F. T. Holstein, J. P. Molnar (with J. A. Hornbeck), M. A. Herlin. Bascom 272.

Tuesday Afternoon

G. A. O. C. Nier, L. A. Wooten, E. F. Lowry. Sterling 113.
H. X-rays and Optical spectroscopy. Bascom 165.
I. J. H. Van Vleck, R. G. Sachs, Arthur Roberts, G. D. Adams (with A. T. Nordsieck). Bascom 272.

Wednesday Morning

J. Nuclear spins and moments; artificial radioactive substances. Bascom 272.
K. Diverse topics; post-deadline papers, if any. Bascom 165.

PROGRAMME

MONDAY MORNING AT 10:30

Bascom Hall, Room 165

(H. M. JAMES presiding)

Solid and Liquid States

A1. Observations on Superlattices in Order-Disorder Alloys Using Neutron Diffraction. SIDNEY SIEGEL AND C. G. SHULL, *Oak Ridge National Laboratory.*—The presence of superlattices in the order-disorder alloys Cu_3Au and FeCo subsequent to various heat treatments has been investigated using the neutron diffraction technique. The neutrons emerge from the Oak Ridge National Laboratory reactor and are monochromated by a (200) reflection from a NaCl crystal. After passing through the sample, consisting of filings of the alloy, in a cell chosen to give about 70 percent transmission, the diffracted radiation is detected with a BF_3 counter. In the case of Cu_3Au, for which the neutron scattering cross sections are 7 and 10×10^{-24} cm², respectively, no superlattice lines can be found in the neutron diffraction pattern for samples known to be ordered by conventional x-ray evidence. In the case of FeCo superlattice lines indicating complete order are found in samples slowly cooled from 800°C, whereas no order is found in the case of samples quenched from elevated temperatures or severely cold-worked. In the case of FeCo the neutron technique is successful because of the relatively large difference in nuclear scattering cross section, 12×10^{-24} cm² for Fe, 1.5×10^{-24} cm² for Co, while x-ray methods are made difficult because of the nearly identical electronic scattering cross section for x-rays of neighboring elements.

A2. Theory of Electrical Resistivity in Tellurium* V. A. JOHNSON, *Purdue University.*—By using an a.c. method to eliminate the Ettingshaussen effect, Bottom[1] has obtained Hall curves as functions of temperature between 85°K and 600°K for a number of tellurium samples. The samples were made by grinding, melting, and casting either commercial or purified tellurium; the ingots so produced were practically isotropic. Bottom has also measured the resistivities of these samples over the same temperature range. Analysis of these curves shows that the theory of resistivity[2] developed from the study of germanium alloys explains the resistivity behavior of tellurium. The low temperature resistivity may be treated as the sum of resistivities due to scattering by lattice ions and by impurity ions. The hole mobility, associated with lattice scattering only, is given approximately by $2.7\times10^{6}T^{-1}$ cm²/volt sec. The ratio of electron to hole mobility is calculated as 1.0. The intrinsic activation energy is found to be about 0.38 ev.

* This work was assisted by a Signal Corps contract.
[1] V. E. Bottom, Bull. Am. Phys. Soc. **23**, No. 3, 21 (1948), G2.
[2] K. Lark-Horovitz and V. A. Johnson, Phys. Rev. **69**, 258 (1946).

A3. Neutron-Bombarded Germanium Semiconductors. R. E. DAVIS,* W. E. JOHNSON, K. LARK-HOROVITZ,* and S. SIEGEL, *Purdue University* and Oak Ridge National Laboratory.*—It has been shown recently[1] that in germanium semiconductors bombarded by deuterons and alpha-particles lattice defects are produced which act as acceptors, thus producing "hole" conduction (*P*-type) (as tested by direction of rectification, Hall effect, and photo-effect). *P*- and *N*-type germanium samples with known electrical characteristics have been irradiated with neutrons in the Oak Ridge reactor; resistivities in *N*-type semiconductors increase under neutron irradiation until the donators are neutralized, and the resistance reaches a maximum; under continued irradiation the conductivity increases again. In *P*-type germanium the conductivity increases steadily with neutron irradiation and values 100 to 200 times the original conductivity have been reached. Whereas the deuteron induced lattice defects are healed by prolonged heat treatment at 400°C, only part of the induced neutron defects are healed in a comparable time interval. Experiments with commercial *N*-type germanium rectifiers indicate changes in the forward and backward direction in agreement witht he conclusion that the *N*-type germanium has been converted to *P*-type. The effect seems more pronounced in Cd-shielded samples.

* The work at Purdue was supported by a Signal Corps Contract.
[1] K. Lark-Horovitz, Bleuler, R. Davis, and D. Tendam, Bull. Am. Phys. Soc. **23**, No. 3, 25 (1948), K3.

A4. On the Measurement of the Hall Effect in Semiconductors.* I. ISENBERG, B. R. RUSSELL, AND R. F. GREENE, *University of Pennsylvania.*—An investigation was made of the short circuiting due to the electrodes in Hall effect experiments on rectangular samples. Formulas derived give the ratio of the measured voltage to Hall voltage as a function of l, the length across which the voltage is applied, w, the width across which the Hall voltage is measured, and the point of measurement. It is found, for example, that for $l/w=2$ the ratio of voltage measured at the center of the sample to Hall voltage is

0.930. If $l/w \geq 4$, the error made is less than 0.3 percent. In terms of the ratio of measured voltage to applied voltage the greatest sensitivity is obtained for $l/w < \frac{1}{4}$. This ratio is equal to $0.742\mu B$ and, for this geometry, is independent of l/w. μ is the mobility of the carrier and B the magnetic field strength. It has been shown for homogeneous slabs that, when point electrodes are used, the Hall voltage depends only on the total current, the magnetic field, and the thickness of the sample but is otherwise independent of the shape of the slab. Experiments verify these results will be described.

* This work was supported in part by Bureau of Ships.

A5. Small Angle Bragg Reflections from Collagen. PAUL KAESBERG, H. N. RITLAND, AND W. W. BEEMAN, *University of Wisconsin.*—The large periodicities in collagen have been investigated using a two crystal spectrometer in the parallel position. The spectrometer is then equivalent to a slit geometry of high resolution. Samples were placed midway between the two crystals and the scattered x-rays scanned by rotation of the second crystal. The first through seventh orders and the ninth order have been completely resolved with wet collagen and relative intensities determined with an accuracy of about 10 percent. With dry collagen, the reflections are much less intense. The first order reflection from wet collagen has a full width at half-maximum of about 20 seconds with FeKα radiation. The periodicity calculated from the order spacings was 675A. for wet collagen and 643A for dry collagen, in good agreement with results of other investigators using standard diffraction methods.[1]

[1] R. S. Bear, J. Am. Chem. Soc. 66, 1297 (1944).

A6. Electron Microscopy of Monolayers. H. T. EPSTEIN, *University of Michigan.*—With the aid of the shadow-casting technique of Williams and Wyckoff it has been possible to study the structure of organic acid monolayers with the electron microscope. The layers were deposited on collodion-covered microscope screens by the Langmuir-Blodgett dipping technique. Heights of mono- and multilayers of stearic acid and cerotic acid were measured and were found to agree well with heights given by previous indirect methods. The use of monolayers in finding the heights of minute objects will be discussed. It may also be possible to report on preliminary work with the oleophobic type of monolayer.

A7. Breaking Strength Dispersion in Nylon Yarns. WALLER GEORGE AND RICHARD LATORRE, *Naval Research Laboratory.*—Measurements of breaking strength of continuous multifilament low twist Nylon yarns (8 g.p.d.) are usually observed to lie within a wide range of strength values. Relatively large numbers of strength measurements using constant rate of load application techniques are reported for a sixfold increase in nominal gauge length. The observed frequency distributions and cumulative distributions for various specimen lengths are analyzed for the existence of a probability density function determining the frequency of observation of particular strength values for tests of unit volumes of the material. Distributions from Nylon yarns are given which indicate that the probability density, if it exists, is not Gaussian. However, more detailed analysis of data for short relative to longer gauges shows that the corresponding ratio of statistical sample sizes is independent of strength only for the region of low strengths. For the remaining region this ratio increases rapidly with strength indicating either that the "effective" length of the short sample increases, which is unlikely, or more probably that this "effective" length for longer lengths decreases with increasing strength. This suggests that for low twist and short gauge lengths twist is unimportant, while for longer specimens of same unit twist the total twist limits the length effective in determining the sample size and, correspondingly, increasing the dispersion in the higher strength ranges.

A8. A Twin Transducer for Measuring Mechanical Properties of Rubberlike Solids at Audiofrequencies. ROBERT S. MARVIN,* EDWIN R. FITZGERALD, AND JOHN D. FERRY, *University of Wisconsin.*—Apparatus has been developed for measuring the dynamic viscosity and rigidity of rubberlike solids in small oscillating deformations. A plate rigidly attached between two identical coils in two permanent magnet loudspeakers shears a pair of disk-shaped samples when a driving current is passed through one coil. The output voltage from the other coil is compared in amplitude and phase with the driving current. The amplitude of motion is extremely small. Representative data for the dynamic viscosity and rigidity of polyisobutylene over the range 30 to 700 c.p.s. will be given.

* Carbide and Carbon Chemicals Corporation Fellow in Physical Chemistry.

A9. The Fracture of Liquids. JOHN C. FISHER, *General Electric Research Laboratory.*—A liquid subjected to negative pressure is metastable; vapor bubbles form spontaneously and grow until the pressure of the system rises to the equilibrium vapor pressure. The rate of bubble formation is calculated from the theory of nucleation, and the negative pressure p_t that gives one bubble (i.e., fracture) in t seconds is determined. p_t is very nearly independent of t and is proportional to σ^4 where σ is the surface tension. Subcooled liquids such as glass also are metastable under negative pressure; cracks form spontaneously and grow until the pressure rises to the equilibrium vapor pressure. Nucleation theory leads to an expression for the fracture stress of glass that is proportional to $(E^3\sigma^3)^{\frac{1}{4}}$ where E is the elastic modulus. The transition from high temperature cavity-nucleated fracture to low temperature crack-nucleated fracture is examined. Fracture strengths calculated from nucleation theory agree satisfactorily with the maximum experimental values, and are an order of magnitude smaller than the forces required for simultaneous separation of all atom pairs cut by a plane surface. The frequent occurrence of premature failure is associated with the presence of pre-existing surface cracks in glass, and of positive contact-angle impurity in contact with liquids.

MONDAY MORNING AT 10:30

Bascom Hall, Room 272

(L. R. INGERSOLL presiding)

Invited Papers

B1. Nuclear Reactions and Level Widths. E. P. WIGNER, *Princeton University.* (30 min.)
B2. (Title to be announced). GREGOR WENTZEL, *University of Chicago.* (40 min.)
B3. Review of Electrostatic Generator Techniques and Recent Results. R. G. HERB, *University of Wisconsin.* (40 min.)

MONDAY AFTERNOON AT 2:15

Bascom Hall, Room 272

(F. W. LOOMIS presiding)

Invited Papers

C1. Structure and Behavior of Rubberlike Materials. H. M. JAMES, *Purdue University.* (45 min.)
C2. Structure of Liquids from Other than X-Ray Evidence. G. ANTONOFF, *Fordham University.* (30 min.)
C3. The Utilization of Physicists and Other Scientists during World War II. M. W. WHITE, *Pennsylvania State College.* (40 min.)

MONDAY AFTERNOON AT 2:15

Bascom Hall, Room 165

(R. G. SACHS presiding)

Reactions of Transmutation; Cosmic Rays

D1. Absolute Voltage Determinations of Three Nuclear Reactions. R. G. HERB, S. C. SNOWDEN, AND O. SALA, *University of Wisconsin.*—The large electrostatic analyzer constructed in 1946 at the University of Wisconsin[1] was used to give independent absolute voltage determination of three nuclear reactions. The reactions chosen were, on the old Li 440 Mev scale, the Li(p,n) threshold at 1.86 Mev, the Al(p,γ) resonance at .985 Mev, the F(p,γ) resonance at .862 Mev. Ion beam energies for these reactions were determined from measurements of the analyzer geometry and of the voltages applied to the analyzer. As a check on the dependability of the results the analyzer geometry was changed substantially after one series of runs and all measurements were repeated. Values obtained from the two series of determinations were consistent to better than .05 percent. Final values cannot be given safely until two further measurements are made. A voltage divider which was used in this work is to be checked at the National Bureau of Standards, and the effect of the earth's magnetic field, which has been only roughly estimated, must be carefully explored. Our values now check closely with those obtained by Hanson[2] and final results will be available in June.

[1] R. E. Warren, J. L. Powell, and R. G. Herb, Rev. Sci. Inst. **18**, 559 (1947).
[2] A. O. Hanson and D. L. Benedict, Phys. Rev. **65**, 33 (1944).

D2. Thresholds for Some Photo-Nuclear Reactions. J. MCELHINNEY, A. O. HANSON, AND R. B. DUFFIELD, *University of Illinois.*—The x-rays from the 22-Mev betatron were used to determine (γ,n) and (γ,p) threshold energies. The majority were detected by the induced radioactivity; the others, by the activity induced in rhodium foils by the ejected neutrons. Energies were determined by fixing the observed thresholds of the reactions,

$C^{12}(\gamma,n)C^{11}$, $Cu^{63}(\gamma,n)Cu^{62}$, and $H^2(\gamma,n)H^1$, at 18.7±0.1, 10.9±0.1 and 2.18 Mev, respectively.

Reaction	Half-life	Observed Threshold (Mev)	Detected by
$N^{14}(\gamma,n)N^{13}$	9.9 Min.	10.6±0.2	Activity
$Mg^{26}(\gamma,p)Na^{24}$	14.8 Hr.	13.2±0.5*	Activity
$Mg^{26}(\gamma,p)Na^{25}$	1.0 Min.	15.6±0.5*	Activity
$P^{31}(\gamma,n)P^{30}$	2.5 Min.	12.4±0.2	Activity
$K^{39}(\gamma,n)K^{38}$	7.7 Min.	13.3±0.2	Activity
$Fe^{54}(\gamma,n)Fe^{53}$	8.9 Min.	13.9±0.3	Activity
$Cu^{65}(\gamma,n)Cu^{64}$	12.8 Hr.	10.2±0.4	Activity
$Br^{79}(\gamma,n)Br^{78}$	6.4 Min.	10.8±0.2	Activity
$Br^{81}(\gamma,n)Br^{80}$	18 Min, 4.4 Hr.	10.3±0.2	Neutrons
$Sb^{121}(\gamma,n)Sb^{120}$	17 Min.	9.3±0.2	Activity
$I^{127}(\gamma,n)I^{126}$	13 days	9.4±0.2	Neutrons
$Ta^{181}(\gamma,n)Ta^{180}$	8.2 Hr.	7.8±0.3	Activity
$Bi^{209}(\gamma,n)Bi^{208}$	—	7.3±0.2	Neutrons

* True thresholds may be 1–2 Mev lower.

D3. Proton-Neutron Thresholds in Cl^{37} and K^{41}. H. T. Richards and R. V. Smith, *University of Wisconsin.*—Protons from the Wisconsin electrostatic generator and analyzed by 90° electrostatic deflection have been used to bombard targets of NaCl and K_2O. A BF_3 counter surrounded by paraffin served as a neutron detector. The $Li^7(p,n)Be^7$ reaction was used to calibrate the energy scale by arbitrarily assuming $E_p=1.880$ Mv for the lithium threshold. The $p-n$ threshold in chlorine was then observed to be at 1.639±.003 Mv. Mass values necessitate assigning the reaction to the Cl^{37} isotope. The Q value is then −1.596 Mv which fixes the mass difference of $A^{37}-Cl^{37}$ as 0.903±.02 mMμ. The large probable error is from the uncertainty of the $n-p$ mass difference. A rough calculation of the reaction cross section for protons 50 kv above threshold gives $\sigma(Cl^{37})=10^{-26}$ cm². In the case of the potassium reaction low neutron intensity near threshold prevented comparable precision in the threshold determination. Radioactivity data and abundance considerations indicate that the reaction should be attributed to the K^{41} isotope. The observed threshold is at 1.22±.06 my corresponding to a $Q=-1.19$ Mv. The mass difference $Ca^{41}-K^{41}$ is then 0.47±.07 mMμ. The cross section for protons 100 kv above threshold is estimated to be $\sigma(K^{41})=10^{-27}$ cm².

D4. Proton-Neutron Thresholds in V^{51} and Mn^{55}. R. V. Smith and H. T. Richards, *University of Wisconsin.*—Targets of V_2O_5 and metallic manganese have been bombarded by monochromatic protons from the Wisconsin electrostatic generator. Thresholds for neutron emission have been observed and reaction cross sections estimated. If the $Li^7(p,n)Be^7$ threshold is arbitrarily taken to be 1.880 Mv for the proton energy, then the V^{51} threshold is 1.564±.003 Mv proton energy and corresponds to a Q value of −1.534 Mv. Therefore the mass difference $Cr^{51}-V^{51}$ is 0.837±.02 mMμ with the $n-p$ mass difference accounting for the uncertainty. The cross sections of V^{51} is estimated to be 10^{-27} cm² for protons 50 kv above threshold. The manganese threshold occurs at 1.19±.01 Mv proton energy and corresponds to a $Q=-1.17$ Mv. The mass difference $Fe^{55}-Mn^{55}$ is .45±.02 mMμ. The reaction cross section is about 5×10^{-28} cm² for protons 50 kv above threshold. The cross section estimates are based upon a value of 3×10^{-25} cm² for the lithium $p-n$ reaction.

D5. Protons from the $Li^7(d,p)Li^8$ Reaction.* E. N. Strait, C. G. Stergiopoulos, and W. W. Buechner, *Massachusetts Institute of Technology.*—The reaction $Li^7(d,p)Li^8$ is well known, but the resulting proton group has hitherto been unobserved. A search for this group has been made using a 180-degree annular magnet to analyze the reaction products. Thin lithium targets have been bombarded with deuterons from an electrostatic accelerator, the analysis being at 90 degrees to the incident beam. Photographic detection has been employed. Using this technique, it is possible to distinguish between the reaction protons and the deuterons scattered inelastically from the target backing. A sharp peak of protons is observed, the energy of which is 750 kev when the incident deuteron energy is 1.36 Mev. This leads to a Q of −0.18 Mev, in good agreement with that obtained[1] from the excitation function for the production of radioactive Li^8.

* This work was supported in part by the Office of Naval Research.
[1] Rumbaugh, Roberts, and Hafstad, Phys. Rev. 54, 657 (1938).

D6. Energy and Angle Variation of $C^{13}(d,p)C^{13}$. D. R. Inglis,* N. P. Heydenburg, and E. M. Hafner,** *Carnegie Institution of Washington.*—The yield of protons from the $C^{12}(d,p)C^{13}$ reaction has been observed from 1.5 to 3.6 Mev, at angles 10°, 90°, and 132.5°. At 10° the resonances observed are in reasonable agreement with those observed for gamma-rays and neutrons by Bailey, Frier, and Williams.[1] The resonances at 2.5, 2.65, and 2.95 Mev do not appear in the 90° yield curve. These are also much less prominent at 132.5°. Angular distribution curves have been taken in the vicinity of several of these resonances. Near 2.95 Mev, these curves show that the resonance is most pronounced near 20°. The short range proton group from $C^{12}(d,p)C^{13*}$ has also been observed at the higher deuteron energies. These have less range than the scattered deuterons, and were observed at 132.5° and 160° using a thin target of india ink on silver foil of 0.5 mm stopping power. The Q for this reaction was calculated to be −0.46 Mev in fair agreement with the value −0.52 ±0.7 Mev given by Bennett, Bonner, Hudspeth, and Watt. A search was made for a proton group giving an exicted state of C^{13} at 0.8 Mev above the ground state which has been found in the reaction $B^{10}(\alpha,p)C^{13}$. Such a group was not observed.

* Johns Hopkins University.
** Brookhaven National Laboratory.
[1] Bailey, Frier, and Williams, Phys. Rev. 73, 274 (1948).

D7. Absolute Thick Target Yields from Several (D,n) Reactions.* Lyle W. Smith and P. Gerald Kruger, *University of Illinois.*—The thick target neutron yields of several elements bombarded with 10-Mev deuterons have been obtained by comparing the activity induced in a large tank of $MnSO_4$ solution with the activity induced by a standard Ra-Be source. The yields in all cases are somewhat larger than would be expected from the extrapolation of the available low energy data. The results for deuterium in conjunction with the data of Curtis, Rosen, and Fowler[1] indicate a significant maximum in the yield between 2 and 10 Mev which is expected on theoretical grounds. The

yields range in value from $3.7\pm0.4\times10^{10}$ neutrons/sec/μa for Be to $0.054\pm0.007\times10^{10}$ neutrons/sec/μa for Au. The largest uncertainty in the experiment is caused by the Ra-Be neutron standard.

* This work was supported in part by the Office of Naval Research.
[1] Curtis, Rosen, and Fowler, Phys. Rev. **73**, 648(A) (1948).

D8. Yield of Photo-neutrons from U^{235} Fission Products in Be. S. BERNSTEIN, F. L. TALBOTT, J. K. LESLIE, AND C. P. STANFORD, *Oak Ridge National Laboratory.*—The yield of photo-neutrons from a sample of 25 fission products at the center of a nine-inch diameter Be sphere has been studied. Samples of U^{235} were exposed in the pile for periods of 30 seconds, 15 minutes, six hours, and 74 hours. The photo-neutrons were observed from 0.3 second to about four weeks after the end of the exposure. Curves showing the photo-neutron yield relative to the delayed neutron yield as a function of time are given for these exposure and observation times. A comparison is made between the photo-neutron yield of infinite thicknesses of D_2O and Be for a six-hour exposure. This comparison shows that the yield from Be is less than that for D_2O for times less than about one-half hour after the end of the exposure and that the yield from Be becomes increasingly greater than that for D_2O for times greater than one-half hour. A possible explanation of the relative yields of Be and D_2O with time in terms of the variations of the photo-disintegration cross sections with energy and the average variation of fission product gamma-ray energy with time is proposed.

D9. Equipment for Photographing Cosmic-Ray Cloud-Chamber Tracks at 100,000 Ft. WALTER FRICK, EDWARD J. LOFGREN, FRANK OPPENHEIMER, AND EDWARD P. NEY, *University of Minnesota.*—We have been able to photograph cosmic-ray tracks at an altitude of 100,000 ft. The cloud chambers are carried aloft by a balloon and remain at altitude for several hours. Details of the temperature regulation and the cloud-chamber control equipment will be discussed. The apparatus is housed in a 30″ diameter aluminum sphere and weighs about 60 lb. The constant temperature is maintained by a thermostatically controlled blower which can circulate air from the hot upper part of the sphere which is painted black and the cooler lower section which is polished. The two sections are separated by an insulating barrier. The cloud chamber is in the lower section. The temperature is maintained constant at the lower altitude before the solar engine begins to function by a battery operated heater. This battery is parachute released at an altitude of about 50,000 feet.

D10. Data Obtained from Cosmic-Ray Cloud Chamber Tracks Taken at 100,000 Feet. EDWARD J. LOFGREN, EDWARD P. NEY, AND FRANK OPPENHEIMER, *University of Minnesota.*—Information contained in the pictures of cosmic-ray cloud-chamber tracks taken at an altitude of 100,000 feet will be summarized. Preliminary data on the occurrence of large numbers of heavily ionizing particles which penetrate ½ inch of lead will be presented. The pictures also gives data on the relative amount of soft, penetrating and heavily ionizing components as a function of altitude.

D11. On the Compton Effect for Protons. J. L. POWELL, *University of Wisconsin.*—The scattering of γ-rays by free protons has been studied on the hypothesis that the proton is a Dirac particle whose magnetic moment is described by the well-known Pauli term. The angular distribution[1] of the scattered γ-rays and the total cross section have been calculated for a particle of arbitrary magnetic moment. The total cross section increases linearly with the energy in the extreme relativistic limit. At intermediate energies it is larger than the cross section obtained without the Pauli term (Klein-Nishina formula). Experimental study of this effect would be very difficult on account of the small cross section ($\sim2\times10^{-31}$ cm^2 at 100 Mv). However, it is conceivable that one could observe the recoil protons from Compton scattering of 100-Mv γ-rays. At this energy, one does not expect the meson production which would confuse the results at higher energy. The calculated angular distribution is fairly uniform, and the recoil particles have energies up to 15 Mv. Comparison of quantitative experimental results with this theory would give information concerning the structure of the proton.

[1] The angular distribution has been given, for the special case of a particle of zero magnetic moment, by Batdorf and Thomas, Phys. Rev. **59**, 621 (1941).

D12. On the Bremsstrahlung Produced by Protons. R. G. SACHS AND J. L. POWELL, *University of Wisconsin.*—If the anomalous magnetic moment of the proton can be described in terms of a Pauli interaction with the electromagnetic field, the cross section for bremsstrahlung will increase more rapidly with energy than that of an ordinary Dirac particle. Therefore it might be expected that the high energy primary protons in the cosmic rays will produce an appreciable number of showers. The extreme relativistic cross sections for scattering by pure and cut-off Coulomb fields have been calculated by one of us (J.P.) using the perturbation method. For a pure Coulomb field the cross section increases more rapidly than that of the electron by a factor E^2 (E=proton energy). For the cut-off field the energy dependence fo the ratio is reduced to E, in agreement with the results of the method of Weizsäcker and Williams.[1] The failure of the latter method for the pure Coulomb field is a consequence of the importance of the contribution of short γ-ray wave-lengths to the cross section. One can conclude that for proton energies above 10^{13} ev it is necessary to consider proton-proton collisions within the nucleus as a major factor in bremsstrahlung production. This effect will reduce the cross section because of the recoil of the proton, while on the other hand the greater strength of nuclear forces may increase it.

[1] Batdorf and Thomas, Phys. Rev. **59**, 621 (1941).

MONDAY EVENING AT 7:00

Loraine Hotel

(F. W. LOOMIS presiding)

Dinner of the American Physical Society

TUESDAY MORNING AT 9:45

Bascom Hall, Room 165

(R. G. HERB presiding)

General Nuclear Physics; Apparatus of Nuclear Physics

E1. Binding Energies of α-Particles in Medium-Heavy Nuclides.* TRUMAN P. KOHMAN, *University of Chicago.*—Binding energies of α-particles in medium-heavy nuclides have been estimated by means of the mass equation of Bohr and Wheeler[1] and the packing fraction curve of Mattauch and Flügge.[2] Most nuclides above mass number 140 are energetically capable of α-emission, and are only stabilized by the nuclear potential barrier, the effect of which has also been calculated. The α-disintegration energy generally increases with increasing Z for isobars and with decreasing A for isotopes. Consequently, sufficiently light isotopes of elements in the region from the rare-earths to lead should be α-active. The lighter naturally occurring isotopes of some of the event elements in this region may exhibit barely detectable α-activity. Bombardment with $\gtrsim$100-Mev photons[3] and particles[4,5] should produce sufficiently neutron-deficient nuclides to allow artificial alpha-activity to be observed in competition with β-decay processes in this region.

* Work begun at the Metallurgical Laboratory, Manhattan Engineer District, in 1946.
[1] N. Bohr and J. A. Wheeler, Phys. Rev. **56**, 426 (1939).
[2] J. Mattauch and S. Flügge, *Nuclear Physics Tables* (Julius Springer, Berlin, 1942; Interscience, New York, 1946).
[3] G. C. Baldwin and G. S. Klaiber, Phys. Rev. **70**, 259 (1946).
[4] G. T. Seaborg *et al.*, Phys. Rev. **72**, 739, 740 (1947).
[5] D. H. Templeton, U.S.A.E.C. Document MDDC-1525 (Abstract).

E2. The Ionization Produced by Alpha-Particles in Argon as a Function of Their Energy. WILLIAM P. JESSE AND HAROLD FORSTAT, *Argonne National Laboratory.*—Recently[1] we have shown that the energy of an alpha-particle may be accurately determined by comparison of its total ionization in argon with that of a standard alpha-particle of known energy in cases where the energy difference between the two is small. To compare thus particles of widely differing energies it is necessary to establish first a calibration curve relating the ionization produced by an alpha-particle with its energy. To this end, we have made preliminary measurements of the relative ionization produced by alphas from six natural radioactive substances in the region from 5 to 9 Mev, where the energies are known with high precision. Here the ionization-energy plot is a straight line which, when extrapolated, passes through the origin. In the region of lower energies, where reaction energies are not known with as high precision, it would seem possible to detect any marked change in slope of the above line by measuring the ionization of each of the two particles emerging from an extremely thin sheet, as for instance in the (n,α) reaction for ^{6}Li or ^{10}B. The ratio of the particle energies may be calculated from the consideration of the conservation of momentum. Tentative experiments of this sort are in progress.

[1] W. P. Jesse and H. Forstat, Phys. Rev. **73**, 926 (1948).

E3. Angular Distribution of α's Coincident with U^{235} Fission. L. MARSHALL, *Argonne National Laboratory and University of Chicago.*—From among 7000 U^{235} fissions made by thermal neutrons in uranium impregnated Eastman photographic emulsion *NTB*, 70 α-particles* coincident[1–4] with fission have been found. An analysis has been made of the variation in their average range and numbers with angle between α and short (heavy) fission fragment. The data will be given on slides. No α's less than 4 Mev have been included. The low energy α's emerge more frequently at acute angles to the short fission fragment. The energetic α's emerge at about right angles, as previously found by Wollan *et al.*[4] The longest range α's seem to emerge most probably at about 100° to the short fragment. This agrees qualitatively with the greater electrostatic repulsion of the heavy fragment due to its higher charge. When the two fission tracks are of very different length, the coincident α tends to have an acute angle with the short range fragment and to be of low energy.

* These α-particles were first observed by L. Alvarez. See quotation in 2.
[1] Demers, Phys. Rev. **70**, 974 (1946).
[2] Farwell, Segre, Wiegand, Phys. Rev. **71**, 327 (1947).
[3] San-Tsiang, Zah-wei, Chastel, and Vigneron, Phys. Rev. **71**, 383 (1947).
[4] Wollan, Moak, Sawyer, Phys. Rev. **72**, 447 (1947).

E4. Preliminary Data on the Production of ± Electron Pairs in the Field of an Electron.* J. A. PHILLIPS AND P. GERALD KRUGER, *University of Illinois.*—A 12″ cloud chamber is irradiated with a collimated beam of gamma-rays from CaF_2 bombarded by 10 Mev molecular hydrogen ions. The cloud chamber is situated outside of the tanks surrounding the cyclotron and is provided with a magnetic field of 1535±1 percent oersteds. Only those pairs and triplets occurring in the gas of the chamber are considered. Operating at a pressure of 1.75 atmospheres, 5372 stereoscopic pictures with air gave 509±electron pairs and 18 triplets. With methane, 13,362 pictures gave 1430 electron pairs and 97 triplets. From these data the ratio of the cross sections for pair to triplet production, assuming a Z^2/Z dependence, has the value for air ($Z^2/Z \simeq 7.2$) of 3.94, and for methane ($Z^2/Z \simeq 4$) of 3.69, which are in agreement within statistical limits. A plot of the logarithm of the number of the slow negative electron of the triplets in equal momentum intervals *versus* momentum of the slow negative electron appears to be a straight line.

* This work in part supported by the Office of Naval Research.

E5. Angular Distribution of the Disintegration Products from the $D-D$ Reaction; 1 to 4 Mev. J. M. BLAIR, W. SLEATOR, JR., GEORGE FREIER, E. E. LAMPI, AND J. H. WILLIAMS. *University of Minnesota.**—The angular distributions of the He^3, produced when deuterons bombard deuterons in the energy range from 1 to 4 Mev have been measured using the scattering chamber previously described.[1] These particles can be counted separately from the elastically scattered particles by virtue of their differences in range and ionizing ability. We find that the distribution of the He^3 cannot be described by $(1+A\cos^2\theta)$ as reported by Bennett, Mandeville, and Richards for the neutrons from the same reaction.[2] There are more particles in the forward direction than can be accounted for by that expression and, for the higher energies, there are further anomalies at 90° in the center of mass coordinate system. Work is being done on the distributions of the H^1 and H^3 from the same reaction.

* This work was supported in part by the Office of Naval Research.
[1] Sleator, Blair, Lampi, and Williams, Bull. Am. Phys. Soc. **23**, No. 2 (1948).
[2] Bennett, Mandeville, and Richards, Phys. Rev. **70**, 101A (1946).

E6. Angular Distribution of 1 to 4 Mev Deuterons Scattered by Deuterons. WILLIAM SLEATOR, JR., J. M. BLAIR, GEORGE FREIER, EUGENE LAMPI, AND J. H. WILLIAMS. *University of Minnesota.**—Using the gas filled chamber previously described,[1] cross sections for the elastic scattering of deuterons by deuterons have been measured at energies ½ Mev apart from 1 to 4 Mev, and at angles from 10° to 45°. The reaction products H^1, H^3, and He^3 are also registered in the proportional counter, but these can be distinguished, as described in the previous paper, from the scattered deuterons, and thus the yield of the latter determined. Typical values of the elastic scattering cross sections at two energies, corrected for H^1 and He^3, but not for H^2, which is estimated to contribute one or two percent, are given in barns per unit solid angle in the table.

θ cm	20°	30°	40°	50°	60°	70°	80°	90°
1.50 Mev	4.22	1.30	0.67	.466	.352	.311	.281	.273
3.55 Mev	1.23	0.59	.396	.309	.266	.222	.195	

Results at other energies are similarly regular.

* This work was supported in part by the Office of Naval Research.
[1] Sleator, Blair, Lampi, and Williams, Bull. Am. Phys. Soc. **23**, No. 2 (1948).

E7. A Simple All-Electronic Cloud Chamber Control Circuit. S. BASHKIN AND H. T. RICHARDS, *University of Wisconsin.*—A modified Wynn-Williams thyratron ring circuit functions as a control circuit for a Wilson chamber built for use with the Wisconsin electrostatic generator. The 100 ma delivered by the miniature 2*D*21 thyratrons obviate relays. Three such thyratrons, with plates capacitively coupled, form a ring circuit with three stable states, in each of which only one thyratron conducts. In the first state, the magnetically operated expansion valve is closed. The plate voltage from one of the non-conducting thyratrons charges a condenser in a variable RC circuit (25–150 sec.) until a neon bulb fires, thereby switching the ring circuit to the next stable state in which the chamber is expanded and the camera solenoid activated. A similar RC circuit (0–1 sec.) transfers the system to its third stable state with the camera closed and the chamber still expanded. A pulse from a third RC circuit (5–20 sec. closes the cycle, recompressing the chamber. Other variable RC circuits fire neon bulbs to trigger a flash tube and pulse an ion beam on a target coincident with the chamber's sensitive time. This circuit can be easily adpated to counter control or expanded to have more stable states.

E8. Stabilized High Voltage Supply for Electrostatic Analyzer. R. L. HENKEL AND B. PETREE, *University of Wisconsin.*—A system for measuring and controlling the beam energy of the University of Wisconsin electrostatic generator has been described by Hanson.[1] The high voltage supply for the electrostatic analyzer used in his system has been modified to give better energy control and to simplify voltage adjustment. The new supply furnishes continuously adjustable voltages from 4000 to 40,000 volts to the analyzer with stability better than 0.01 percent. High voltage from a rectifier circuit is compared, by means of a voltage divider, to a potentiometer. The difference or error voltage is amplified about 10^7 times by a galvanometer-phototube amplifier, and the amplified error voltage is applied to the grids of variable-impedance tubes in the high voltage transformer primary so as to decrease the error. Oscillation is prevented with differentiated feed-back. Rapid line voltage fluctuations are not completely compensated for by the galvanometer-phototube amplifier because of its relatively slow response, but these fluctuations are avoided by supplying power to the high voltage transformer from a motor-alternator set with electronic field regulation. With this new method, the beam energy automatically follows adjustments of the potentiometer.

[1] A. O. Hanson, Rev. Sci. Inst. **15**, 57 (1944).

E9. Design of Electrostatic Generator for the University of São Paulo, Brazil. O. SALA, *University of S. Paulo** AND R. G. HERB, *University of Wisconsin.*—A high pressure electrostatic generator for the University of São Paulo is being designed for a maximum voltage of 3.5–4 Mv following the Wisconsin horizontal arrangement. Important design considerations are low cost, simplicity, minimum time for construction, easy operation and high beam current. The pressure tank is to have an inside diameter of 7 feet, a length of 21 feet and a maximum operating pressure of 150 p.s.i. The tank is arranged to roll back for easy access to equipment inside. Inside structure is supported by four textolite tubes, each 10 feet long, giving an insulating length of 9 feet. Two accelerating tubes are provided, one for the ion beam and one for an electron beam to give voltage control. The second tube will also be used for differential pumping. Two concentric high potential electrodes will be used.

* Now at the University of Wisconsin as a Rockefeller Fellow.

E10. Performance of the Allen Type Multiplier Tube for Lithium Ion Counting. A. H. MORRISH AND J. S. ALLEN, *University of Chicago.*—Information concerning the efficiency of an electron multiplier[1] tube used for detection of single Li ions is necessary for He^6 recoil experiments now in progress. Li ions were produced by thermionic emission from a coating of spodumene on a platinum filament. After being accelerated, they were bent by the plates of an electrostatic analyzer through a slit into the multiplier tube. This arrangement prevented the tube from "looking" directly at the ion source. The counting rate was compared to the current, which was determined by sweeping the ions through a larger slit, connected to a balanced type d.c. amplifier. The relative transmission of the slits was determined by comparing counting rates of a beam swept through each slit. Ions from 4.9 to 6.5 kv were used, and showed almost constant counting rates. Pulse height distribution curves were taken for 4.9 and 6.0 kv ions, and were of the same general shape, the 6.0 kv ions giving more counts at all points on the curve. The efficiency for ions of low energy is being investigated.

[1] J. S. Allen, Rev. Sci. Inst. **18**, 739 (1947).

E11. Neutral Region in the Space Charge of a Self-Quenching G-M Counter. C. V. ROBINSON, *University of Wisconsin.*—It is not uncommon for a G-M counter to collect more than twice the original charge, Q_0, on the wire. This is inconsistent with (1) immediate collection of the electrons which leave a purely positive space charge; (2) nearness of space charge to the wire; (3) non-negative field throughout the counter. To explain this large charge collection, assumption (1) may be discarded leading to the following mechanism. In a length dx of the counter, ions produced by avalanching, build out radially leaving a weak field near the wire in which delayed quanta produce ion pairs. In about 10^{-9} sec. ionization has ceased, and the length dx of wire is discharged and surrounded by a neutral region (of + ions and electrons) within a purely positive sheath whose charge is a little more than Q_0dx. As the outer + ions move out, the electrons in the neutral region move in, releasing an equal number of electrons and + ions. The process continues until all electrons are collected and all + ions freed. Then the wire recharges. W. W. Beeman suggested the delayed electron collection.

E12. Multivibrator Quenching of Geiger-Mueller Tubes.[1] B. J. THAMER AND A. F. VOIGT, *Iowa State College.*—Lowering or reversing the sign of the potential on the anode of a Geiger-Mueller tube is an effective way of quenching the tube discharge and allowing the tube to regain its sensitivity rapidly, thus reducing the counting loss at high counting rates. An electronic circuit capable of applying a quenching pulse of any desired width and magnitude has been developed. The amplified G-M tube pulse actuates a multivibrator which triggers the quenching tube.[2] A series of dead-time determinations was made on several G-M tubes using paried samples, keeping the width of the quenching pulse at 12 microseconds and varying its magnitude from 0 to a value sufficient to make the center wire 50 volts negative with respect to the cathode. Quenching pulses in the range from 0 to 400 volts gave dead-times of roughly 290 microseconds. Important factors were the previous history of the tube and its operating potential. When the quenching pulse brought the wire potential within ±50 volts of the cathode, the dead-times were approximately 40 microseconds.

[1] This work was done under contract with the Atomic Energy Commission.
[2] For a similar application see J. A. Simpson, Jr., Phys. Rev. **66**, 39 (1944).

TUESDAY MORNING AT 9:45

Bascom Hall, Room 272

(W. B. NOTTINGHAM presiding)

Invited Papers of the Division of Electron Physics

F1. Imprisonment of Resonance Radiation in Ionized Gases. T. HOLSTEIN, *Westinghouse.* (40 min.)

F2. Cathode-Emission Processes in Townsend Discharges. J. P. MOLNAR AND J. A. HORNBECK, *Bell Telephone Laboratories.* (40 min.)

F3. Electrical Discharges in Gases at Microwave Frequencies. M. A. HERLIN, *Massachusetts Institute of Technology.* (40 min.)

TUESDAY AFTERNOON AT 2:15

Sterling, Room 113

(H. B. WAHLIN presiding)

Invited Papers of the Division of Electron Physics

G1. Mass Spectrometry. A. O. C. NIER, *University of Minnesota.* (40 min.)

G2. Sorption of Gases by Metals at Low Pressure—a Study of Getters. L. A. WOOTEN, *Bell Telephone Laboratories.* (40 min.)

G3. The Long-Term Decay of Phosphors under Ultraviolet Excitation. E. F. LOWRY, *Sylvania Electric Products.* (40 min.)

TUESDAY AFTERNOON AT 2:15

Bascom, Room 165

(L. R. INGERSOLL presiding)

X-Rays and Optical Spectroscopy

H1. The MnK Absorption Edges of Manganese and Manganese Compounds. H. P. HANSON AND W. W. BEEMAN, *University of Wisconsin.*—The x-ray K absorption edge of manganese, in the metal and in various compounds, has been measured with a double crystal spectrometer. Striking differences are observed between the edges in homopolar complexes and in ionic crystals. With anions which are not strongly electronegative in their effect, one observes some absorption into levels on the long wave-length side of the main $4p$ absorption. This absorption occurs at the same energy as the $3d$ levels.

H2. Method of Measuring Ratio of Bremsstrahlung Cross Sections. L. H. LANZL, J. S. LAUGHLIN, AND L. S. SKAGGS, *University of Illinois.*—The ratio of cross sections for the production of Bremsstrahlung in elements of nuclear charge Z_1 and Z_2 is measured as follows: two sets of thin, uniform foils, one set of alternate Z_1 and Z_2 foils, the other set all of Z_1 foils, are placed perpendicular to an electron beam and irradiated. The activities of the odd position foils of both sets (Z_1 in both cases) are then measured and plots are made of initial radioactivity *vs.* foil position normalized to the first foil of one of the sets. Such plots are linear[1] if the total foil thickness is small compared to the range of the electrons. The ratio of Bremsstrahlung cross sections for that part of the spectrum above the threshold of Z_1 is then obtained from the ratio of the slopes of the two curves and the number of atoms per unit area in each foil. Using 15.5 Mev electrons from the betatron, the Bremsstrahlung cross section ratio of Ta and Cu, measured under four different conditions, was $6.89 \pm .21$. Elementary theory predicts that the ratio should vary as Z^2 giving for Ta−Cu 6.34. In this measurement Cu corresponded to Z_1 and therefore was the element in which the activity was measured.

[1] L. S. Skaggs, J. S. Laughlin, A. O. Hanson and J. J. Orlin, Phys. Rev. **73**, 420 (1948).

H3. A Photoelectric Technique for Spectral Emissivity Determination Illustrated by Results on Tungsten.* W. B. NOTTINGHAM AND W. E. MUTTER, *Massachusetts Institute of Technology.*—A method of measuring spectral emissivity at a narrow band width over a range of wave-lengths from the near ultraviolet to the near infra-red has been developed. The intensity of various parts of the image of a miniature blackbody source is explored by means of a monochrometer and photomultiplier tube arrangement; the emissivity at a given wave-length and temperature is determined from a measurement of the ratio of the intensity from the surface of the specimen to that from the blackbody cavity. Initial results on tungsten over the range 1300 to 2000°K and 380 to 800 millimicrons are represented by the empirical formula $\epsilon_{\lambda T} = 0.5308 + 5.24 \cdot 10^{-6} T - (9187 + 3.90T) 10^{-5} \lambda$ The variation of the spectral emissivity with wave-length and temperature is in general agreement with results of Forsythe and Worthing.** However, the absolute values are all $1\frac{1}{2}$ to 2 percent lower.

* This work has been supported in part by the Signal Corps, the Air Materiel Command and the O.N.R.

** W. E. Forsythe and A. G. Worthing, Astrophys. J. **61**, 152 (1925).

H4. Electromagnetic Shift of S Levels in He II.* J. E. MACK AND N. AUSTERN, *University of Wisconsin.*—Work on the line λ4686A° ($n=4 \rightarrow n=3$) of ionized helium has been continued. The third most intense component ($3_1 - 4_1$) has been separated, presumably into $3s_1 - 4p_1$ and $3p_1 - 4d_1$. A Fabry-Perot etalon with a 15 mm-spacer was crossed with the previously used diffraction grating in order to obtain this result.

* The work is supported by the Office of Naval Research.

H5. The Continuous Absorption Coefficient of the Helium Atom. SU-SHU HUANG, *Yerkes Observatory.* (*Introduced by S. Chandrasekhar.*)—The continuous absorption

coefficient of HeI from its ground state as well as its two metastable states has been carried out. The wave functions used for these three states are those of the Hylleraas type derived from the Ritz principle. The constants of these wave functions were determined, as Hylleraas apparently did not solve for them. For the wave functions of the continuous states, the hydrogenic approximation was used. The cross sections for each of the three states have been determined in terms of the matrix elements of the dipole moment, momentum and acceleration and compared in the manner of Chandrasekhar's discussion of the negative hydrogen ion.*

* Astrophys. J. 102, 223, 395, (1945).

H6. Rydberg Denominators in the Principal Series of the Alkali Metal Atoms. J. G. HIRSCHBERG, JR., *University of Wisconsin.*—The Ritz series fit is discussed for the Rydberg denominators calculated from the accurate term values of Kratz.[1]

[1] H. R. Kratz, Ph.D. Thesis University of Wisconsin, 1942; Phys. Rev. (to be published).

H7. Structure of the ^2D-Terms of Li^7. K. W. MEISSNER, L. G. MUNDIE,[1] AND P. STELSON, *Purdue University.*—Interferometric wave-length measurements of the lithium arc spectrum were carried out by employing an atomic beam light source. The great sharpness of the spectral lines permitted determination of the splitting of several ^2D-terms. The values for the first four members of the diffuse series are: $\Delta\nu = 0.0372$, 0.015, 0.010, and 0.005 cm^{-1}. All investigated D-terms exhibit regular term order.

[1] Now at Naval Research Laboratory, Washington, D. C.

H8. Infra-Red Dispersion of N_2O and C_2H_4. C. F. HAMMER, A. G. PIEPER, AND R. ROLLEFSON. *University of Wisconsin.*—The indices of refraction of N_2O and C_2H_4 have been measured for wave-lengths between 1 micron and 16 microns. The method has been described previously.[1] The index of refraction is the sum of a series of terms, each term being a function of the characteristics of a particular absorption band. In the infra-red region the terms due to ultraviolet absorption can be lumped into a single term which is almost constant. Each of the remaining terms is of the form $A_i/[2\pi^2 C(\nu_i^2 - \nu^2)]$; where A_i is the integrated absorption coefficient,[2] and ν_i is the wave number corresponding to the ith band. These measurements, then, make the determination of A_i possible without actually taking measurements in the band. The accuracy of the A_i's is dependent on the magnitude of the absorption intensity and the wave-length region of the particular band. We believe the accuracy to be better than 4 percent for the strongest bands.

[1] R. Rollefson and R. Havens, Phys. Rev. 57, 710 (1940).
[2] M. Thorndike, A. J. Wells and E. Bright Wilson, Jr., J. Chem. Phys. 15, 157 (1947).

H9. Band Spectrum of HgTl. J. GIBSON WINANS AND WILLARD J. PEARCE,* *University of Wisconsin.*—Vibrational analyses have been made for the HgTl band systems with maxima of intensity at 6550, 5200, 4580, and 3810A. The light source was a Tesla discharge with external electrodes through a quartz tube containing Hg and Tl. The 3810 system was obtained also in absorption. The following constants were obtained:

ν_{00}	ω_0'	$\omega_0'x_0'$	ω_0''	$\omega_0''x_0''$	D_0'	D_0''
15339.9	82.2	0.157	102.08	2.08	4100 cm^{-1}	1132 cm^{-1}
15289.4	82.27	0.144	100.8	2.29	4100 cm^{-1}	1081 cm^{-1}
22621.5	81.23	0.077	105.97	0.268	4100 cm^{-1}	2015 cm^{-1}
26253.2	15.53	0.060	26.2	0.69	474 cm^{-1}	250 cm^{-1}

* Now at University of Texas, El Paso.

H10. Spin-Orbit Effect in the Hyperfine Structure of the Ammonia Inversion Spectrum. J. M. JAUCH, *State University of Iowa.*—The recent measurement of the hyperfine structure in the ammonia inversion spectrum by Simmons and Gordy[1] indicated a significant discrepancy with the theoretical formula for the satellite separation. It is pointed out that this effect can be interpreted as due to the interaction of the magnetic dipole moment of the nitrogen nucleus with the rotation of the molecule. The interaction term in the Hamiltonian is of the form $-\mu H'(J, I)$, where μ is the magnetic moment of the N^{14} nucleus, H' the effective magnetic field at the position of the nucleus, J the angular momentum vector of the molecule, and I the spin vector of the nucleus. Theoretically, the constant $H'(J, K)$ is expected to depend explicitly on the rotational quantum numbers, J, K. However, a rough estimate indicates that the variation of H' is less than the uncertainty resulting from the measurements. Best agreement with the experimental values is obtained by assuming $H' = 15 \pm 5$ gauss. This explanation permits also a redetermination of the quadrupole interaction parameter which in frequency units is found to be $(eqQ) = 4.107 \pm 0.015$ mc/sec.

[1] J. W. Simmons and W. Gordy, Phys. Rev. 73, 713 (1948).

H11. Phenomenological Quantum-Electrodynamics. K. WATSON AND J. M. JAUCH, *State University of Iowa.*—The relativistic quantum formalism of the electromagnetic field in a medium characterized by a dielectric constant ϵ and a magnetic permeability μ has been developed. The total energy and momentum of the field do not form a nulvector in this theory. The quantization is given both in the Hamiltonian form as well as in the symmetrical four-dimensional formalism. When the interaction with charges is introduced the longitudinal components can be eliminated with the help of the subsidiary condition. The resulting Coulomb energy in the Hamiltonian depends explicitly on the velocity of the medium. If the velocity of the medium with respect to the particle exceeds that of $v = C/n$, a particle at rest can radiate spontaneously. This is traced to the fact that in this case light quantas may occur with negative energy. The total emission probability for such radiation is infinite if n is independent of the frequency. Only if dispersion is introduced does the expression become finite. In the latter case it agrees exactly with the classical expression for Čerenkov radiation given by Tamm and Frank.[1]

[1] Comptes Rendus 14, 109 (1937).

TUESDAY AFTERNOON AT 2:15

Bascom Hall, Room 272

(F. W. LOOMIS presiding)

Invited Papers

I1. Line-Breadths in Radiofrequency and Microwave Absorption Spectra. J. H. VAN VLECK, *Harvard University.* (35 min.)

I2. The Interpretation of the Magnetic Moments of Light Nuclei. R. G. SACHS, *University of Wisconsin.* (30 min.)

I3. Nuclear Spins and Moments Obtained from Microwave Spectra. ARTHUR ROBERTS, *State Univeristy of Iowa.* (30 min.)

I4. Absorption of 10–20 Mev Quanta. G. D. ADAMS AND A. T. NORDSIECK, *University of Illinois.* (30 min.)

WEDNESDAY MORNING AT 9:45

Bascom Hall, Room 272

(J. H. VAN VLECK presiding)

Nuclear Spins and Moments; Artificial Radioactive Substances

J1. Hyperfine Structure of 30 Zn^{67}.* O. H. ARROE, *University of Wisconsin.*—A study of the hyperfine structure of the ZnI lines $4_s4_p\ ^3P_{012}-4_s5_s\ ^3S_1$, from a sample enriched in Zn^{67} (borrowed from the United States Atomic Energy Commission) shows hyperfine structure intervals verifying the value 5/2 for the nuclear spin of Zn^{67}, tentatively assigned by Rasmussen.

* The work is supported by the Office of Naval Research.

J2. A Variation of the Nuclear Resonance Experiment. EDWARD R. MANRING, JOHN R. ZIMMERMAN, AND DUDLEY WILLIAMS, *The Ohio State University.*—Roberts has described a method for measuring nuclear gyromagnetic ratios by means of a super-regenerative oscillator circuit and a communications receiver. We have made extensive experiments using a similar arrangement with a specially designed audio amplifier as a detector. With the usual arrangement in which a solid or liquid sample is mounted inside the oscillator coil, saturation effects introduced considerable difficulty, since the r.f. magnetic fields were larger than necessary for the experiment but, owing to inherent characteristics of super-regenerative circuits, could not be satisfactorily reduced. We have attained satisfactorily low values for the r.f. magnetic field by placing the sample between the plates of a condenser and using the r.f. magnetic field associated with the displacement currents. The parallel plate condenser containing the sample is mounted with the plates parallel to the pole faces of a large electromagnet. As the air gap in the magnetic circuit can be made smaller than when the coil is mounted in the magnetic field, more effective use is made of iron in the magnet circuit and, for a given field current, a more favorable Boltzmann factor can be attained. Although the arrangement we have used has been found to be convenient in special cases, its ultimate limitations are essentially the same as those indicated by Bloch and Purcell.

J3. The Beta Spectrum of C^{14}.* LAWRENCE M. LANGER, C. SHARP COOK, AND H. CLAY PRICE, JR., *Indiana University.*—The momentum distribution of the negatrons emitted by C^{14} has been investigated in the high resolution, 40 cm radius of curvature, shaped field magnetic spectrometer. The sources were prepared from high specific activity material made available at Oak Ridge through the efforts of Norris and Snell. Spectra were obtained using sources of average thickness 0.13 mg/cm², 0.29 mg/cm², and 0.97 mg/cm². The backing in all cases was 0.02 mg/cm² Zapon. The Zapon counter window transmits electrons down to 2.0 kev. Under these conditions, all three sources yield spectra which are the same for all energies from $W=1.12$ mc² to the end point. Over this region, the Fermi plot is not a straight line, but has, rather, a very slight curvature away from the energy axis. This curvature is not explained by the use of Fermi selection rules for a second forbidden transition of the type $J=1$ with no parity change. S^{35}, measured under essentially identical conditions does yield a straight line Fermi plot over the same region which is curved for C^{14}. The extrapolated Fermi end point for C^{14} is at $W_0=1.306$ mc² corresponding to 156.3 ± 1.0 kev. The end point for S^{35} is found to be 169.1 ± 0.5 kev.

* This work is supported by a grant from the Frederick Gardner Cottrell fund of the Research Corporation and by the Office of Naval Research.

J4. Radioactive Isotopes of Germanium and Arsenic. D. A. McCown, L. L. Woodward, M. L. Pool, and H. L. Finston, *The Ohio State University.*—The germanium fraction from zinc bombarded with alpha-particles showed long half-life of positron activity, presumed to be the 195-day germanium period. Gallium bombarded with deuterons gave evidence of no period longer than 11 days in the germanium fraction. From intensity considerations, the 195-day period should have occurred if it were Ge^{69}. Hence this long period has been assigned to Ge^{67}. Gallium bombarded with deuterons showed in the germanium fraction a strong positron activity of 1.66-day half-life. Deuteron bombardment of germanium showed a similar period in the germanium fraction, but this period was an electron emitter, being produced by decay of 12-hour Ge^{77} into As^{77}. Hence the positron emitting period of 1.66 days in germanium is assigned to Ge^{69}. A strong sample of radioactive Ge^{71}, decaying with the 11-day half-life, has produced on a curved crystal camera the characteristic x-ray lines of gallium. Simultaneous deuteron bombardment of two samples of selenium, enriched respectively in isotopes 74 and 76,* confirms in the arsenic fraction the location of the positron emitting period of 1.08 days half-life as that due to As^{72}.

* Supplied by the Y-12 plant, Carbide and Carbon Chemicals Corporation, through the Isotopes Division, U. S. Atomic Energy Commission, Oak Ridge, Tennessee.

J5. Artificial Radioactivity from Enriched Se^{74} and Se^{76}. L. L. Woodward, D. A. McCown, M. L. Pool, and H. L. Finston, *The Ohio State University.*—A radioactive Br^{74} isotope of 106-minute half-life has been produced by $Se^{74}(d,2n)$ and $Se^{74}(p,n)$ reactions. The Se^{74} used was enriched electromagnetically from 0.9 percent to 14.1 percent.* The period was not observed by similar reactions on Se^{76}, enriched from 9.5 percent to 41.5 percent.* A positron end-point energy of about 1.5 Mev was observed. No evidence of gamma-radiation has been found in the activity. A radioactive Br^{77} isotope of about 48-hour half-life has been produced by a (d,n) reaction on enriched Se^{76} and by an (α,p) reaction on enriched Se^{74}. A radioactive Kr^{77} isotope of 65-minute half-life has been produced by a $Se+\alpha$ reaction, and located by an α-particle bombardment of enriched Se^{74}. A positron end-point energy of 1.7 Mev has been observed by aluminum absorptions. Gamma-radiation and K-capture have also been observed. The Kr^{79} isotope has been produced by an (α,n) reaction on enriched Se^{76}. The half-life of this isotope is computed as 1.30-days with gamma-radiation present. The 4.4-hour Br^{80} isotope has been produced by a $Se(\alpha,p)$ reaction. Positron emission has been observed with an end-point energy of about 0.8 Mev.

* Supplied by the Y-12 plant, Carbide and Carbon Chemicals Corporation, through the Isotopes Division, U. S. Atomic Energy Commission, Oak Ridge, Tennessee.

J6. Evidence for a Double Isomer in Rh^{103}. H. F. Gunlock and M. L. Pool, *The Ohio State University.*—The x-ray activities in the previously reported 17-day Pd^{103} and 56-minute Rh^{103} have been photographed and found to be the K-series of rhodium. No shift or doubling, due to a possible double electron jump, appears when comparison is made with the spectrum of fluorescent rhodium. Spectrograms of 39.9 and 42.7 Kev electron groups have been obtained from samples of $Rh+d$ and $Ru+d$. These cannot be interpreted as L- and M-conversion electrons, since no group is found where the K-conversion electrons, required by the K-series x-rays, would appear. Considering the two groups as K-electrons, no L- or M-electrons are found near 60 Kev. The gamma-rays responsible for the K-conversion would have energies near 63.1 and 65.9 Kev. These, if present, are of very low intensity. The data appear to indicate two isomers of stable Rh^{103}. The metastable states would have energies of 63.1 and 65.9 Kev and decay to the ground state by emission of gamma-rays which appear to be entirely converted in the K-shell alone.

J7. "Cross-Over" Transitions in Gamma-Ray Spectra. V. Myers and A. Wattenberg, *Argonne National Laboratory.*—The possibility was investigated of there being very weak high energy gamma-rays in certain isotopes than are known at present. In some instances, these gamma-rays may be "cross-over" transitions, i.e., transitions directly from the higher levels to the ground state rather than a cascade process. The technique consisted of placing the radio-isotope inside a beryllium or heavy water target, and a BF_3 pulse ion chamber was used to detect any photoneutrons emitted. 37-minute Cl^{38} and 60-day Sb^{124} produced photoneutrons in D_2O (2.18 Mev threshold) while 34-hour Br^{82} produced photoneutrons in Be (1.63 Mev threshold). It is not known whether the Cl^{38} gamma-ray is a "cross-over" transition, or whether it is the "2.15"-Mev gamma reported by Siegbahn[1] and lying just at the limit for photo-disintegration in heavy water.

[1] K. Siegbahn, Arkiv. F. Math. Astr. och Fys. **32A**, 9 (1945).

J8. The Decay Scheme of 47-hr Sm^{153}. S. B. Burson and C. O. Muehlhause, *Argonne National Laboratory.*—As seen by an ordinary argon filled mica end window counter the 47-hr period in Sm^{153} has been shown to have the following radiations:

.78 Mev β^- ~	100	percent,
EuL x-rays ~	.25	percent,
EuK x-rays ~	.12	percent,
110 Kev γ-rays ~	.03	percent,
610 Kev γ-rays ~	.003	percent.

By coincidence measurements using two mica end window counters we have also shown the existence of direct coincidences of these radiations as follows:

β^-, e^- (e^- ~ L conversion of γ_{110}) ~	90	percent,
β^-, x (K and L-rays) ~	7	percent,
β^-, γ_{110} ~	2	percent,
x, x (K x-rays) ~	.85	percent,
x, γ_{110} (K x-rays) ~	.15	percent.

No delayed coincidences $>1.5\mu s$ were found. We therefore conclude (1) the existence of an almost totally converted level in Eu^{153} of energy <100 kev which is in cascade with γ_{110}, and (2) that the weak γ_{610} must follow a weak β^- branch of ~200 kev from the 47-hr state in Sm.

J9. The Beta Spectra of W^{185} and Os^{193}. D. Saxon, *Argonne National Laboratory.*—The survey of the heavy

elements begun with Au^{198} has been continued in the neighboring region.[1] For W^{185}, the half-life has been determined as $73.2\pm0.5d$, checking the older measurements. The end point from the Kurie extrapolation is 0.430 ± 0.010 Mev. The recent measurement of S. Jnanananda[2] gives 0.675 Mev, a value much outside the experimental errors. Since the end point of Ir^{192} is essentially this value, and in view of the large neutron cross section of Ir^{191} as compared to W^{184}, it is suggested that Jnanananda's sample had ≥ 0.1 percent impurity of Ir^{191}. The half-life of Os^{193} found was 16.1 ± 0.2 days. However the effect of the 100-day Os^{185} K-capture correction could bring this down to the 15-day value found by L. Katzin and M. Pobereskin. The end point found was 142 ± 3 kev. By coincidence methods, Wiedenbeck and Chu obtained 0.64 Mev, a value very close to that for Ir^{192}. From the K, L, and M conversion line the energy of one γ is 127 ± 2 kev, checking that of Cork *et al.* Similarly, the L and M lines of a new low energy γ give 39 ± 1 kev. The above conversion lines all decay with the 16-day period.

[1] D. Saxon, Phys. Rev. **73**, 811 (1948).
[2] S. Jnanananda, Phys. Rev. **72**, 1124 (1947).

J10. Studies on the Radiation of Hf^{181}.* A. F. VOIGT AND B. J. THAMER, *Iowa State College.*—Absorption and coincidence absorption measurements have been made on the radiation from 46-day Hf^{181}, obtained by pile thermal neutron bombardment. The energy of the principal gamma-radiation was found to be 0.52 ± 0.05 Mev while that of the beta-radiation was $0.63\pm.03$ Mev by Feather analysis. Measurement with a magnetic field showed only negative electrons. The coincidence study showed a conversion electron of 0.12 Mev energy in coincidence with the beta-ray. Beta-spectrometer studies have shown a 0.12 Mev electron to be an L conversion electron of a 0.132 Mev gamma-ray which electron is probably the one observed here, the K electron being too soft (0.065 Mev) to be detected. However, DeBenedetti[1] has reported a 0.11 Mev electron to be emitted in a 22μsec. delayed transition. Since the resolving time of the present circuit[2] is 0.67 μsec. it is impossible that the delayed electron would give the observed coincidence rate. Without knowing whether both of these are L electrons the energies of the coincident and delayed transitions cannot be stated with certainty.

* This work was done under contract with the Atomic Energy Commission.
[1] S. DeBenedetti and F. K. McGowan, Phys. Rev. **70**, 569 (1946).
[2] The coincidence circuit and counter tubes used with it were built by and under the supervision of D. S. Martin.

J11. Activities Produced by Bombardment of TiO_2 with Pile Neutrons.[1] R. E. HEIN AND A. F. VOIGT, *Iowa State College.*—The radioactive isotopes produced by epi-Cd neutron bombardment of titanium dioxide have been investigated using the Argonne heavy water pile. A chemical separation on the irradiated TiO_2 was effected for the purpose of identifying radioactive products from (n,γ), $(n,2n)$, (n,p) and (n,α) processes. The following activities were identified: Ti^{51}, Sc^{46}, Sc^{47}, and Ca^{45}. These identifications were based on observed beta-ray energies and half-life measurements as well as chemical evidence. The cross sections for the formation of these activities from their appropriate titanium isotopes and an upper limit for Sc^{48} were estimated. Since no monitoring sample was present, the estimate for the cross sections was based on measured activities, radiation log and neutron flux. The cross sections for the formation of the listed isotope from the appropriate Ti isotope and based on the total flux of neutrons of all energies are: $Ti^{51}\sigma=8\times10^{-28}$ cm², $Sc^{46}\sigma=2.5\times10^{-31}$ cm², $Sc^{47}\sigma=6.9\times10^{-30}$ cm², $Sc^{48}\sigma=1.3\times10^{-31}$ cm² and $Ca^{45}\sigma=3\times10^{-32}$ cm². The presence of a contaminant, Sb^{123}, with an estimated $\sigma_{act.}=8\times10^{-24}$ cm², hindered the investigation. It is of interest that the 83-hour Sc^{47} was produced by an n,p reaction, while the 44-hour Sc^{48}, which is reported as a product of such a bombardment, was not observed.

[1] This work was done under contract with the Atomic Energy Commission.

WEDNESDAY MORNING AT 9:45

Bascom Hall, Room 165

(W. W. BEEMAN presiding)

Diverse Topics

K1. Secondary Emission from Thoria on Platinum and Tantalum. H. E. MENDENHALL, *Bell Telephone Laboratories.*—Thorium dioxide has been used as a cathode coating material for some magnetrons and power tubes. The secondary emission properties or a film of thoria about 5×10^{-4} cm thick has been studied on platinum and tantalum ribbons. At temperatures up to 400 or 500°C there is evidence from the shape of the δ *vs.* bombarding energy curves of a charging of these surfaces when measurements are made on D.C. At higher temperatures below which primary emission becomes appreciable, the resistance of the coating becomes low enough so that δ's up to 3.4 have been measured without evidence of charging. The thoria coating on tantalum appears to activate when heated to 2000°K probably due to reduction of some thoria to thorium in the coating film.

K2. The Transport Properties of Non-Polar Gases.* JOSEPH O. HIRSCHFELDER, R. BYRON BIRD, AND ELLEN L. SPOTZ, *The University of Wisconsin.*—In the kinetic theory of gases, all of the transport properties are expressed in terms of a set of collision integrals. We have evaluated these on the assumption that the energy of repulsion is inversely proportional to the twelfth power and the energy of attraction to the sixth power of the separation. The transport properties are then reduced to known functions of the reduced mass; the minimum energy of interaction, ϵ; and the collision diameter for low velocity collisions, r_0. The values of ϵ and r_0 for a large number of common gases are determined from recent measurements of viscosity and compared with values previously determined from second virial coefficients. These constants and the tabulated integrals at 84 different temperatures are used to predict the coefficient for thermal diffusion as a function of temperature and the results are very interesting. Our calculations should have a mechanical error of the order of one part in 300, and at the lowest temperatures they must be corrected for quantum effects.

* This work was carried out under contract with the Navy Bureau of Ordnance.

K3. The Equilibrium Assumption in the Theory of Absolute Reaction Rates.* C. F. CURTISS AND J. O. HIRSCHFELDER, *University of Wisconsin.*—The usual theory of absolute reaction rates involves the approximation that the molecules in the transition stage are in statistical equilibrium with the reacting molecules—an approximation difficult to justify. It is shown that this approximation is equivalent to taking the distribution in velocities of the reacting molecules to be Maxwellian. The chemical reaction itself causes the distribution function to deviate somewhat from the equilibrium Maxwellian distribution, since in general only fast molecules react. The perturbed distribution function has been obtained, using a generalization of the Chapman-Enskof methods of kinetic theory. The effect of the perturbation on the rate of a bimolecular reaction has been considered. The influence of the rate of transfer of energy among the various internal degrees of freedom has been obtained by considering two extreme cases. In one case we assumed that the transfer of energy takes place extremely slowly; in the other case that it takes place extremely rapidly. In both cases the rate of reaction obtained differs by less than 8 percent from the value obtained on the basis of the usual approximation.

* This work was carried out under contract with the Navy Bureau of Ordnance.

K4. Unitary Field Theory and Cosmic Magnetism. JEAN MARIANI, *Institute for Advanced Study* (Introduced by L. Brillouin).—We adopt the view that the difficulties in the way of constructing a unified field theory stem from the use of unoperational notions, i.e., notions lacking experimental significance according to L. W. Bridgman. In the present work we consider the notion of an unobservable (an isolated system, a unique electromagnetic field in vacuum, etc.) to be inadmissible. We generalize the law of inertia in a way suggested by Elie Cartan, H. Mandel, and L. P. Eisenhart, using like E. Schrödinger a non-symmetrical affine connection in Riemannian space-time. We emphasize the fact that the antisymmetrical part of our connection, like Eisenhart's, is a function of the velocity of the test particles in the field, so that the geometry defined by our connection cannot be described independently of the test particles. We base our explanation of electromagnetism upon this fact. Our point of view leads us to a geometry of paths similar to those of O. Veblen, Eisenhart and others. Bodies regarded as electrically neutral in the usual theory are here considered as charged. It follows that a rotating celestial body possesses a magnetic field and it is shown that this leads in the case of static equilibrium to Blackett's formula.

K5. Theory and Applications of the Parallel T Resistance-Capacitance Network. C. E. BERGMAN AND G. H. FETT, *University of Illinois.*—This paper is a general study of the theory and applications of the parallel T resistance-capacitance network, using matrix algebra. The basic theory is presented, and equations are developed for the conditions of null, for the transfer characteristic, and for input (or output) impedance. The effect of loading is considered; simplified equations, resulting from certain special component relationships, are presented. Practical design factors are given. Applications given include reviews and analyses of the uses of the circuit as a compact low-frequency filter to suppress a single frequency, as a filter for a power supply, as a frequency or impedance bridge, and as the feedback loop for a frequency-selective amplifier or frequency-stabilized oscillator. An analysis is given of the problem of imparting band-pass characteristics to the frequency-selective amplifier by means of two parallel T networks.

TO BE READ BY TITLE

T1. Radiations from Columbium (95).* C. E. MANDEVILLE AND M. V. SCHERB, *Bartol Research Foundation of the Franklin Institute.*—The 35-day columbium activity was produced by the fission process in the pile at Oak Ridge. Chemical purification was carried out for the removal of phosphorous, zirconium, copper, and iron as possible impurities. Aluminum absorption indicated the presence of the characteristic soft beta-rays having an energy of about 0.13 Mev. Coincidence absorption of secondary electrons gave a maximum gamma-ray energy of 0.92 Mev. The beta-gamma coincidence rate indicated that the beta-rays are followed by 0.94 Mev of gamma-ray energy. A gamma-gamma coincidence rate of 0.28×10^{-3} coincidence per gamma-ray was also observed. The writers had previously assigned the 0.92 Mev gamma-ray to the zirconium parent element.[1] This apparently resulted from an incomplete chemical separation and from the fact that the 0.92 Mev gamma-ray is very intense. The previously reported[1] coincidence rates of zirconium (95) suggest that only gamma-rays of energy 0.3 or 0.4 Mev follow the zirconium beta-rays.

* Assisted by the Office of Naval Research.

[1] M. V. Scherb and C. E. Mandeville, Bull. Am. Phys. Soc. **23**, No. 3, 56 (1948).

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